Economic Analysis and Comparison of Waste Water Resource Heat Pump Heating and Air-conditioning System

Chunlei Zhang Suilin Wang Hongbing Chen Yongzheng Shi
Master Student Professor Lecturer Lecture
Key Laboratory of Heating, Gas Supply, Ventilating & Conditioning Engineering
Beijing Institute of Civil Engineering and Architecture，100044
Beijing & China
E-mail: zcl17908@sohu.com

Abstract: Based on the heating and air-conditioning system of a high-rise residential building in Northern city, this paper provides a discussion on the choice and matching of different types of Waste Water Resource Heat Pump (WWRHP) heating and air-conditioning systems. With the economic analysis and comparison, the best scheme of WWRHP heating and air-conditioning system is obtained.

Key words: Waste Water Resource Heat Pump; heating and air-conditioning; best way; technology; economic

1. INTRODUCTION

With the implementation of global sustainable development, WWRHP technology has been more and more widely used for cooling and heating, especially for the heating and air-conditioning system, which is very meaningful for energy conservation and environment protection, and is also more adaptable for the sustainable development. According to the application and development demand of WWRHP, it is very important to choose a suitable heating and air-conditioning type, optimize system scheme, and meet the demand of economic and reliable heating and air-conditioning system.

Based on the heating and air-conditioning system of a high-rise residential building in Northern city, this paper provides a discussion on the choice and matching of different types of Waste Water Resource Heat Pump (WWRHP) heating and air-conditioning systems. With the economic analysis and comparison, the best scheme of WWRHP heating and air-conditioning system is obtained.

2. THE ANALYSIS ON DIFFERENT SCHEMES OF WWRHP HEATING AND AIR CONDITIONING SYSTEM

2.1 Basic Information

In this area: outdoor design dry bulb temperature for winter heating is -12℃, outdoor design dry bulb temperature for winter air-conditioning is -15℃, heating duration is long for 135 days, the outdoor average temperature for winter heating is -2.7℃, outdoor design dry bulb temperature for summer air-conditioning is 31.2℃, daily mean temperature for summer air-conditioning is 26.1℃, air-conditioning duration is long for 90 days; The temperature of intermediate water in this area for winter is 12℃, summer of that is 22℃; the building has 18 floors each has 8 inhabitants, the global architectural area is 18879m^2 , the using global architectural area is 13414 m^2, each floor is 2.9 miters high, the architectural area of each floor is 1048.84 m^2, the using architectural area is 745.2 m^2, the thermo-technical performance of envelope is up to the second design standard, on energy conservation heat consumption index is 20.8W/ m^2 , electric rate for this districts is 0.65 Yuan /KWh (industry), 0.5 Yuan /KWh （civil）, architectural drawing is shown in Fig.1.

2.2 Schemes and Features

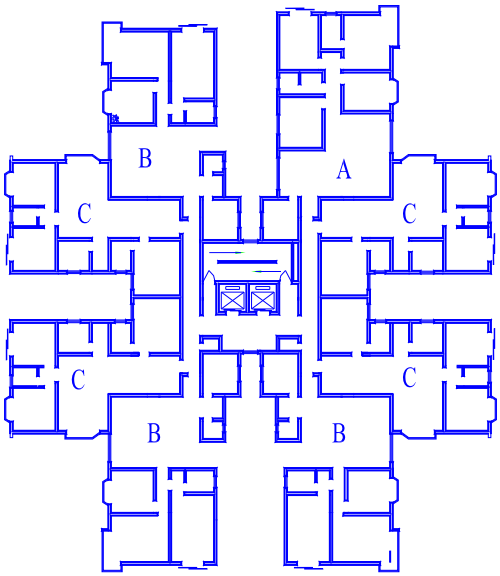
Exploring the waste water source for temperature heat sources has four schemes as following: Scheme 1 is adopting floor heating system all the year; Scheme 2 is adopting fan-coil system all the year; Scheme 3 is adopting fan-coil system cooling for

summer and floor heating system heating for winter; Scheme 4 is adopting split type air conditioner for summer and floor heating system for winter. Principle of the WWRHP is shown in Fig. 2.

Radiant floor heating system is very comfortable in winter, indoor design temperature is permit to lower 2~3 ℃ therefore cut the load, and take the best use of low level energy; thermal inertia of the room is good, but thermal comfort in summer is not comfortable so its application is limited. Fan-coil system, its room adjustment is flexible: amenity standards of summer is high, but in winter is not and fluctuate of indoor temperature is big under un-continuous running.

3. INVESTMENT ANALYSIS

3.1 Heating and Cooling Load



A: building area is 157.96 m^2 B: 139.4 m^2 C: 118.27m^2 (terrace calculated in half）

Fig 1 Ground plan of typical floor

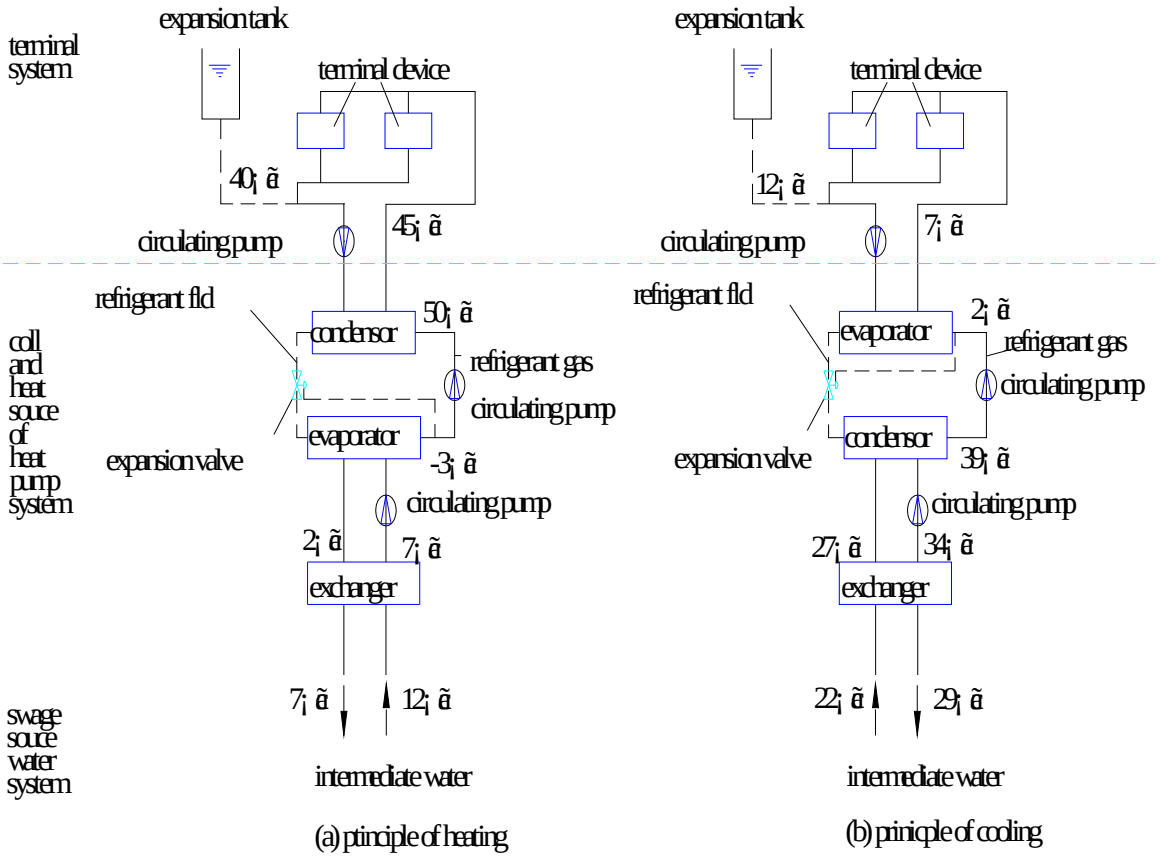


Fig.2 Principle of the swage source heat pump heating and air-conditioning

Table 1 Load calculation

Scheme		Load data per unit (w/m^2)	Area(m^2)	Total load (kw)
Floor heating	Winter	48	18879	906
Fan-coil	Winter Summer same	60		1133
		80		1510
		100		1888

. The load of two schemes of heating air-conditioning is shown in Table.1. Considering different operating mode of fan-coil system, the heating and cooling load of winter and summer adopt different value according to the operating and intermittent time.

3.2 Investment

The total first cost of heating and air-conditioning system sourced by waste water in the small town contains heat source, district pipe network and heating and air-conditioning system, considering the cost of different districts is different according to their size .Here mainly calculating the cost of indoor building heating air-conditioning system and equipment room.

The cost of indoor building heating and air conditioning system contains indoor floor heating system or fan-coil system and inner pipe system of the building. The cost of equipment room contains: units, pipes of equipment room, component and meters, circulating water pumps and water treatment device. First cost of floor heating system contains: heating pipes and construction cost. construction of the floor adopts wet structure [1], heating pipes adopts PE-X costs about 30 Yuan / m^2, construction costs 12 Yuan / m^{2}fan-coil system and floor heating system both adopt the household style and share the riser pipe [2], I adopted PE-X, and used the same riser pipe, and water system of air-conditioning is two-pipe direct return system. Calculation result is shown in Table 2 and 3.

The forward data indicated that: The first cost of scheme 1 is the lowest :scheme 3 is second, scheme 4 is the highest, if increase fan-coil system based on scheme 1 the first cost will increase 59%~104%, if increase split type air conditioner, the first cost will increase 72%~108%.

Tab. 2 First cost of different parts

Category	First Cost											
Floor Heating	Wan Yuan						Yuan / m^2					
	98						51.6					
Fan-coil System	60 (w/m^2)				80 (w/m^2)				100 (w/m^2)			
	Domestic		Intake		Domestic		Intake		Domestic		Intake	
	Wan Yuan	Yuan/ m2	Wan Yuan	Yuan/ m2	Wan Yuan	Yuan/ m2	Wan Yuan	Yuan/ m2	Wan Yuan	Yuan/ m2	Wan Yuan	Yuan/ m2
	78	41	113	60	86	45	136	72	100	53	160	84
Unit Room	96	51	130	68	126	66	171	90	156	82	213	112.
Split Type Air Conditioner	114~185 (Wan Yuan)						85~138 (Yuan/ m^2)					

Tab. 3 First cost of different schemes

Scheme	Content	First Cost	
		Wan Yuan	Yuan/ m^2
1	Floor heating system all the year	171~198	91~105
2	Fan-coil system all the year	174~307	92~162
3	Floor heating in winter fan-coil in summer	272~404	144~214
4	Floor heating in winter split air-conditioning	294~411	163~218

Tab. 4 Operating cost of different parts one year

Classification			Operating Cost/year	
			Wan Yuan	Yuan/ m^2
Fan-coil system in summer	60 (w/ m^2)		0.9 ~1.1	0.5 ~0.6
	80 (w/ m^2)		1.3 ~1.5	0.7 ~0.8
	100 (w/ m^2)		1.5 ~1.7	0.8 ~0.9
Fan-coil system in winter	60 (w/ m^2)		3 ~3.6	1.6 ~1.9
	80 (w/ m^2)		4.3 ~4.9	2.3 ~2.6
	100 (w/ m^2)		4.9 ~5.5	2.6 ~2.9
Unit in summer	60 (w/ m^2)		8.2 ~9.3	4.3 ~4.9
	80 (w/ m^2)		11 ~12	5.8 ~6.6
	100 (w/ m^2)		14 ~16	7.2 ~8.2
Unit in winter	48 (w/ m^2)		27 ~32	14 ~17
Circulating water pumps	60 (w/ m^2)~100 (w/ m^2) In summer		0.7~1.4	0.37~0.75
	60 (w/ m^2)~100 (w/ m^2) In winter		2.3~4.3	1.2~2.3
	48 (w/ m^2)	winter	1.8	1

Tab. 5 Operating cost of different schemes one year

Scheme	Content	Operating Cost	
		Wan Yuan	Yuan/ m^2
1	Floor heating system all the year	36~42	19~22
2	Fan-coil all the year	41.6~58.4	22~31
3	Floor heating in winter and fan-coil in summer	38.5~53	20~28
4	Floor heating in winter and split air-conditioning in summer	43.4~59.3	23~31

4. OPERATING FEE ANALYSIS

Energy consumption of WWRHP heating and air-conditioning system, with regard to floor heating, it contains the energy consumption of the units and circulating water pumps, operating cost contains the operating cost of units and circulating water pumps; with regard to fan-coil, it contains the energy consumption of units and circulating water pumps and fan-coil, the operating cost contains the operating cost of units and circulating water pumps and fan-coil, both schemes contain maintenance charge .The result is shown in Table 4 and 5.

The forward data indicated that: operating cost of scheme 1 is the lowest; scheme 3 is second, scheme 4 is the highest; the operating cost of scheme 1 can save 6.5%~38.4%, compared with scheme 2, can

save 17%~39%compared with scheme 4; the operating cost of scheme 3 can save 7.5%~34%, compared with scheme 2, save 11%~35% compared with scheme 4.

5. ENERGY CONSERVATION AND ENVIRONMENTAL BENEFIT

Convert to standard coal according to the operating energy consumption of scheme — floor heating in winter and fan-coil in summer, in winter it is 8.8~10.3 kg/m^2.a, in summer it is 3.2~5.2 kg/m^2.a; compared with traditional indoor radiator system sourced by district boiler house in winter and split air-conditioning in summer scheme(standard coal in winter is 25 kg/m^2.a, in summer is 9.7 kg/m^2.a),can save standard coal 19.2~22.7 kg/m^2.a, equal to 363~429 t/a, at the same time cut down discharge of 55 % ~65 % CO_x、SO_x、NO_x, reduces the pollution further.

Adopting WWRHP system, save the cost of exploring well, compared with soil source heat pump or water source heat pump, economizing on land, saving cost of welling, and it won't construct destruction to the underground environment and source, not only save the precious water source but also change the waste water into treasure and reused it and improve primary energy efficiency.

6. CONCLUSIONS

With the technical and economic analysis on four different schemes of WWRHP heating and air-conditioning system, the following conclusions are obtained:

1) The floor radiation heating and cooling system has the lowest investment. If fan-coil system is added, the investment will increase 59~104%, but the operating fee will be the lowest, about 6.5~39% lower than that of other schemes; the "floor radiation heating system + fan-coil system" has an investment 12~19% lower than that of the "floor radiation heating system + divided air-conditioning system", and the operating fee is 11~35% lower.
2) The floor radiation heating and cooling system has the best comfort in winter and the fan-coil heating and air-conditioning system has the best comfort in summer; the divided air-conditioning system involves flexible installation.
3) WWRHP heating and air-conditioning system has so many advantages including high COP and little pollution with the comparison of traditional heating and air-conditioning systems.

REFERENCES

[1]. Technical specification applied for floor radiant heating (JGJ142-2004). China architecture industry press.. 20-30. (In Chinese)

[2]. Xiangdong Li, Xiaoming Yu. Design and installation of household metering heating China architecture industry press. 2004, 48-196. (In Chinese)